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FORM PTO-1390 REV. 5-93 US DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE **TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371**		ATTORNEYS DOCKET NUMBER **P01,0147** U.S.APPLICATION NO. (if known, see 37 CFR 1.5) 09/857481
INTERNATIONAL APPLICATION NO. **PCT/DE99/03834**	INTERNATIONAL FILING DATE 1 December 1999	PRIORITY DATE CLAIMED 3 December 1998

TITLE OF INVENTION
"METHOD AND DEVICE FOR REDUCING A NUMBER OF MEASURED VALUES OF A TECHNICAL SYSTEM"

APPLICANT(S) FOR DO/EO/US
Stefan SCHÄFFLER and Thomas STURM

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay.
4. ☒ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. ☒ A copy of International Application as filed (35 U.S.C. 371(c)(2))
   a. ☒ is transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☐ has been transmitted by the International Bureau.
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US)
6. ☒ A translation of the International Application into English (35 U.S.C. 371(c)(2).
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. §371(c)(3))
   a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☐ have been transmitted by the International Bureau.
   c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   d. ☒ have not been made and will not be made.
8. ☐ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).)
10. ☒ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C.371(c)(5)).

Items 11. to 16. below concern other document(s) or information included:

11. ☒ An Information Disclosure Statement under 37 C.F.R. 1.97 and 1.98; **(PTO 1449, Prior Art, Search Report)**.
12. ☒ An assignment document for recording. A separate cover sheet in compliance with 37 C.F.R. 3.28 and 3.31 is included. **(SEE ATTACHED ENVELOPE)**
13. ☒ A FIRST preliminary amendment.
    ☐ A SECOND or SUBSEQUENT preliminary amendment.
14. ☒ A substitute specification and a marked up version of the specification.
15. ☒ A change of power of attorney and/or address letter.
16. ☒ Other items or information:
    a. ☒ Submittal of Drawings
    b. ☒ **EXPRESS MAIL #EL 843728827 US, dated June 4, 2001.**

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U.S. APPLICATION NO. (if known, see 37 C.F.R. 1.5)	INTERNATIONAL APPLICATION NO	ATTORNEY'S DOCKET NUMBER
09/857481	PCT/DE99/03834	P01,0147

17. ☒ The following fees are submitted:

	CALCULATIONS	PTO USE ONLY
BASIC NATIONAL FEE (37 C.F.R. 1.492(a)(1)-(5): Search Report has been prepared by the EPO or JPO .... $860.00 International preliminary examination fee paid to USPTO (37 C.F.R. 1.482) ..... $700.00 No international preliminary examination fee paid to USPTO (37 C.F.R. 1.482) but international search fee paid to USPTO (37 C.F.R. 1.445(a)(2) .... $770.00 Neither international preliminary examination fee (37 C.F.R. 1.482) nor international search fee (37 C.F.R. 1.445(a)(2) paid to USPTO .... $1040.00 International preliminary examination fee paid to USPTO (37 C.F.R. 1.482) and all claims satisfied provisions of PCT Article 33(2)-(4) .... $ 96.00		
ENTER APPROPRIATE BASIC FEE AMOUNT =	$ 860.00	
Surcharge of $130.00 for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 C.F.R. 1.492(e)).	$	

Claims	Number Filed	Number Extra	Rate		
Total Claims	10 - 20 =		X $ 18.00	$ .00	
Independent Claims	2 - 3 =		X $ 80.00	$	
Multiple Dependent Claims			$270.00 +	$	

	CALCULATIONS	PTO USE ONLY
TOTAL OF ABOVE CALCULATIONS =	$ 860.00	
Reduction by 1/2 for filing by small entity, if applicable. Verified Small Entity statement must also be filed. (Note 37 C.F.R. 1.9, 1.27, 1.28)	$	
SUBTOTAL =	$ 860.00	
Processing fee of $130.00 for furnishing the English translation later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(f)). +	$	
TOTAL NATIONAL FEE =	$ 860.00	
Fee for recording the enclosed assignment (37 C.F.R. 1.21(h). The assignment must be accompanied by an appropriate cover sheet (37 C.F.R. 3.28, 3.31). $40.00 per property +		
TOTAL FEES ENCLOSED =	$ 860.00	
	Amount to be refunded	$
	charged	$

a. ☒ A check in the amount of $ 860.00 to cover the above fees is enclosed.

b. ☐ Please charge my Deposit Account No. __________ in the amount of $ _______ to cover the above fees. A duplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 501519. A duplicate copy of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 C.F.R. 1.494 or 1.495 has not been met, a petition to revive (37 C.F.R. 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

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IN THE UNITED STATES ELECTED OFFICE
OF THE UNITED STATES PATENT AND TRADEMARK OFFICE
UNDER THE PATENT COOPERATION TREATY-CHAPTER II

"**PRELIMINARY AMENDMENT**"

APPLICANT: Stefan SCHÄFFLER et al.

SERIAL NO.: EXAMINER:

FILING DATE: ART UNIT:

INTERNATIONAL APPLICATION NO.: PCT/DE99/03834

INTERNATIONAL FILING DATE: 1 December 1999

INVENTION: METHOD AND DEVICE FOR REDUCING A NUMBER OF MEASURED VALUES OF A TECHNICAL SYSTEM

Hon. Assistant Commissioner for Patents
Box PCT
Washington D.C. 20231

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SIR:

Amend the above-identified international application before entry into the national stage before the U.S. Patent & Trademark Office under 35 U.S.C. §371 as follows:

IN THE SPECIFICATION

Please substitute the specification in the file with the enclosed substitute specification in compliance with 37 CFR 1.125(b). Furthermore, a separate marked up copy of the specification that shows all changes relative to the previous specification is also enclosed.

IN THE CLAIMS

Please cancel all claims without prejudice and add new claims 11-20 as follows.

WE CLAIM:

11. A method for modeling a technical process of an engineering plant comprising:

measuring an initial set of empirical values at various steps of a technical process using sensors while said technical process is operating based on a predetermined set of parameters;

screening out a set of empirical values from the initial set of empirical values for reducing a size of the initial set of empirical values to obtain a screened set of empirical values by:

dividing the initial set of empirical values into classes based on a predefined criteria, followed by assessing each empirical value in each class with respect to a predefined first threshold value, and if a result of said assessing step lies below said predefined first threshold value, then screening out said empirical value, further assessing each class with respect to a predefined second threshold value, if a result of said assessing step lies below the second predefined threshold value, then, screening out said class; and

modeling said technical process using said screened set of empirical values to obtain a model result.

12. A method according to claim 11, wherein the predefined criteria in said dividing step is based on the predetermined first set of parameters.

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13. A method according to claim 11, further comprising the step of :

determining an empirical value associated with a transient phase of the technical process resulting from a modification of the predetermined set of parameters; and

screening out the empirical value associated with the transient phase.

14. A method according to claim 11, further comprising the step of:

reducing a number of empirical values in a class by selecting a representative empirical value for the class.

15. A method according to claim 14, wherein the representative empirical value is an average of the empirical values in the class.

16. A method according to claim 14, wherein the representative empirical value is one of a maximum value and a minimum value of the empirical values in the class.

17. A method according to claim14, wherein the representative empirical value is a median of the empirical values in the class.

18. A method according to claim 11, further comprising the step of:
screening out a class with fewer number of empirical values than a predefined number.

19. A method according to claim 11, wherein the result of said assessing step is a difference of the empirical value in the class with the predefined first threshold value.

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20. A system for modeling a technical process of an engineering plant comprising:

a series of sensors for measuring and acquiring an initial set of empirical values at various stages of the technical process while the technical process is operating based on a predetermined set of parameters; and

a central processing unit being supplied with the initial set of empirical values, which screens a set of empirical values out of the initial set of empirical values using a screening algorithm to obtain a screened set of empirical values by: a division of the first set of empirical values in to classes based on a predetermined criteria, followed by an assessment of an empirical value within a class with respect to a predefined first threshold value, if a result of the assessment lies below a predefined first threshold value, then, the empirical value is screened out; and a further assessment of the class with respect to a predefined second threshold value; if a result of the further assessment lies below the second predefined threshold, then, screening out the class,

said screened set of empirical values utilized for a simulation of the technical process to obtain a model result.

REMARKS

The foregoing amendments to the specification and claims under Article 41 of the Patent Cooperation Treaty place the application into a form for prosecution

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before the U.S. Patent and Trademark Office under 35 U.S.C. §371. Accordingly, entry of these amendments before examination on the merits is hereby requested.

Respectfully submitted,

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SPECIFICATION

TITLE

METHOD AND ARRANGEMENT FOR REDUCING A NUMBER OF MEASURED VALUES OF A TECHNICAL SYSTEM

BACKGROUND OF THE INVENTION

Field of the Invention

The present inventive method relates to a method and an arrangement for reducing a number of measured values of a technical system.

Description of the Related Art

A technical system, for example a process engineering plant, supplies a large quantity of measured values per unit time, using different measured-value pickups (sensors). In the course of a number of days or weeks, a quantity of data accumulates which requires a correspondingly high computational power to process it. If the measured values are to be used to adapt or reset the technical system, operations are often necessary whose complexity admits only some of the measured values. It is then a great disadvantage to select a specific number of measured values arbitrarily from the quantity of all measured values and to process them further, since measured values with low significance, for example measured values with a high degree of interference, have a considerable influence on the overall result and falsify the latter considerably.

SUMMARY OF THE INVENTION

The object of the invention is to specify a method and an arrangement for reducing measured values, it being ensured that the remaining measured values have a high significance with regard to their description of the technical system. In order to achieve the object, a method of reducing a number of measured values of a technical system is specified, in which the measured values are divided into classes in accordance with predefined criteria. The measured values in a class are assessed and those measured values whose assessment lies below a predefined first threshold value are screened out.

Screening out the measured values results in a reduction with regard to the number of measured values. A considerably reduced number of measured values is thus available for further processing. The further processing can be carried out with a lower computational outlay as compared with the non-reduced number of measured values.

In one embodiment, the classes themselves are also assessed. In particular, a class whose assessment lies below a predefined second threshold value can be screened out. This results in an additional reduction in the number of measured values.

In another embodiment, one criterion for the division into classes consists in that, for each class, measured values relating to a predefinition of setting parameters of the technical system are determined. Typically, the technical system is set using a predefined number of setting parameters and after the setting has been carried out, there follows a (mostly time-delayed) reaction of the system to the setting parameters

(transient response, transient process of the system). After the setting operation, a specific quantity of measured values which can be associated with the transient process are therefore picked up, measured values which are associated with the predefined set of setting parameters continuing to accumulate after the transient process has concluded (transition to steady-state operation). By adjusting the setting parameters, a new class is determined. All the measured values which respectively accumulate after an adjustment to the setting parameters belong in their own class. Another development consists in that measured values within a class which can be associated with the respective transient process are screened out. In addition, erroneous measured values can be screened out. In many cases, the setting of large technical systems depends on long-term, steady-state operation. Measured values which relate to the transient process (of short duration in comparison with the steady-state operation after the transient process has concluded) are expediently screened out, since measured values for the steady-state operation are falsified by them. In particular within the context of modeling the technical system, the measured data about the steady-state behavior of the technical system are of interest.

One refinement of this embodiment consists in reducing the number of measured values in a class in that at least one representative value for the measured values in the class is determined. Such a representative value may be:

a) an average (e.g. a sliding average) of the measured values of the class,

b) a maximum value of the measured values of the class,

c) a minimum value of the measured values of the class,

d) a median.

In the case of variant (d), one advantage resides in the fact that it is always possible to determine a value which is actually present, while the average (a) does not itself occur as a value.

Depending on the application, a suitable selection for determining the representative value of a class may be made.

An entire class with measured values can be screened out if said class contains less than a predefined number of measured values.

Another refinement consists in that those measured values are screened out which differ from a predefinable value by more than a predefined threshold value.

The predefinable value can be an average of all the measured values of the class or a measured value to be expected in response to the respective setting parameters of the technical system.

A development consists in that the measured values which are reduced in number are used for the simulation and/or the draft design of this or another technical system.

The draft design of the technical system can in this case comprise both adaptation and redrafting of this or another technical system.

In addition, within the context of the simulation, the behavior of the technical system can be checked by using the reduced number of measured values, with the objective of altering the system for developing a new system with altered predefinitions.

In addition, in order to achieve the object, an arrangement for reducing a number of measured values of a technical system is specified which has a processor unit, which processor unit is set up in such a way that the measured values can be divided into classes in accordance with predefined criteria. Measured values in a class can be assessed, measured values whose assessment lies below a predefined first threshold value are screened out.

This arrangement is particularly suitable for carrying out the method according to the invention or one of its developments explained above.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 shows a block diagram which contains steps in a method for reducing measured values.

Fig. 2 shows a schematic sketch of a recovery boiler.

Figs. 3 through 5 show input variables, actuating variables and outward variables of the recovery boiler.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Fig. 1 shows a block diagram which contains steps in a method of reducing measured values. In a first step 101, the measured values are divided into classes. In particular, the division into classes is carried out with the effect that all the measured values which belong to one set of setting parameters are combined in one class. To this extent, each alteration to the setting parameters of the technical system found a

new class. In particular, altering the setting parameters is associated with a transient process of the technical system, this process, as opposed to a steady-state behavior, containing extreme fluctuations in the measured values. In a step 102, individual measured values within one class are screened out. These may be, for example, erroneous measured values, that is to say measured values which exhibit a high deviation with respect to the other measured values or an average of the measured values or measured values from the transient process. There are a number of possible ways of screening out individual measured values within a class:

1. Measured values which are too poor (based on a predefined comparative value);
2. Measured values which belong to a transient process;
3. Measured values which are erroneous;
4. Determining a representative measured value as a representative for a plurality of measured values, in that the representative measured value is determined as an average of the measured values in a class or as a maximum value or a minimum value of these measured values.

Measured values of this type are preferably not taken into account; they are removed from the respective class. This results in a considerable reduction in the number of measured values. In a step 103, individual classes are screened out. One criterion for screening out an entire class consists in that the class contains less than a predefined number of measured values. In a step 104, the measured values reduced

in number are used for further processing. Further processing is, in particular, a simulation and/or a draft design of the technical system.

Fig. 2 shows a schematic sketch of a recovery boiler. In the following text, by using the example of a "recovery boiler", an exemplary embodiment of the method described above will be illustrated.

In the paper and pulp industry, various chemicals and also heat and electrical power are needed for the digestion of pulp. With the aid of the recovery boiler, the chemicals used and additional thermal energy may be recovered from a thickened waste process liquor (black liquor). A measure of the recovery of the chemicals is of critical importance for the economy of the overall plant.

The black liquor is burned in a char bed 201. In the process, an alkaline melt is produced and flows away via a line 202. In further process steps, the chemicals used are recovered from the constituents of the alkaline melt. Heat of combustion which is released is used to generate steam. The combustion of the waste liquor and therefore the recovery of the chemicals begins with the atomization of the black liquor via atomizer nozzles 204 into a combustion chamber 203. As they fall through the hot flue gas, particles of the atomized black liquor are dried. The dried liquor particles fall onto the char bed 201, first combustion and chemical reduction taking place. Volatile constituents and reaction products pass into an oxidation zone, in which oxidizing reactions proceed and in which the combustion is completed.

Important objectives for the control of the recovery boiler are the steam production in order to obtain power, compliance with emission values from environmental points of view and the efficiency of the chemical reduction.

The combustion operation, and therefore the objectives, are controlled in particular by the supply of air at three levels (primary air (PA), secondary air (SA), tertiary air (TA)). The overall process is subject to numerous influences, which have to be taken into account during the modeling:

a) the measurement of the variables is subject to fluctuations which are often extreme;

b) influencing variables which are not measured and cannot be measured exist;

c) at each alteration to the settable parameters transient processes occur;

d) the technical plant becomes soiled and is cleaned at predefined intervals, which has the effect of a drift over time in each case in the system behavior.

The measured variables of the overall process are subdivided into input variables (cf. Fig. 3) and output variables (cf. Fig. 5). Measured variables are stored every minute. Four of the input variables are simultaneously also actuating variables (also: settable parameters; cf. Fig. 4). The actuating variables are to be viewed substantially as free parameters of the overall process which can be set independently of one another. Some of the other input variables are more or less dependent on the actuating variables. According to one predefinition, the variables “BL Front Pressure” and “BL

Back Pressure" are always to be regulated equally in the recovery boiler. The four actuating variables (cf. Fig. 4) are preferably to be stored as actuating variables (with the desired, preset value) and as input variables (with the measured, actual value).

In the recovery boiler, one problem consists in the fact that, depending on the settable parameters, specific objectives, which are defined via measured variables, have to be met. Here, a three-stage procedure is selected in order to solve the problem:

1. The objectives to be considered are modeled by means of stochastic methods, these models being updated by means of new measurements (data-driven, empirical modeling). In this case, it is expedient to use not just a single model but global models for the identification of interesting areas in a parameter space determined by the objectives, and to use local models for the exact calculation of optimum operating points. The models used are assessed by means of quality measures.

2. If the models considered are not sufficiently accurate because of the state of the data (quality measure), new operating points are deliberately evaluated in order to improve the model (experimental design). In addition, by using global stochastic optimization methods with regard to the objectives, attractive regions are identified on the basis of the current global model.

3. For the local optimization, local models are constructed, and the data sets which are available are, if appropriate, deliberately expanded (experimental design).

The objectives are physical/technical or economic criteria which, as a rule, have to meet boundary conditions and/or safety conditions. It is often the case that a number of these criteria have to be considered at the same time. A stochastic model can be used in particular for the purpose of simulating the objectives to be optimized and their dependence on the parameters to be set in the computer. This is necessary when measurements are very costly or very time-consuming. In the case of safety requirements, possible hazardous situations can be avoided.

In the case of the recovery boiler, on-line optimization, which is based on a plurality of items of data, is necessary, since the physical/chemical processes cannot be modeled quantitatively with sufficient accuracy and because the behavior of the plant is subject to fluctuations in the course of operation. The knowledge about this behavior must continually be expanded by means of the deliberate selection of new operating points. Therefore, within the context of on-line optimization, the above-described three-stage procedure of stochastic modeling at mathematical optimization is to be recommended.

DESCRIPTION OF THE INPUT VARIABLES

The a input variables ($a \in N$, N: set of natural numbers) generally depend on n actuating variables $n \in N$ and on random effects. They can be described as follows:

Let (Ω, S, P) be a probability space and B^v be a Borel σ-algebra over R^v (R: set of real numbers) for each $v \in N$. The input variables are represented by a projection φ which can be measured via $B^n \times S - B^a$:

$\varphi: R^n \times \Omega \rightarrow R^a$ (1). The definition set of the projection φ is a cartesian product of two sets. If one considers the respective projections onto the individual sets, then the following projections are obtained:

$$\varphi_X: \Omega \rightarrow \mathbf{R}^a,\ \omega \rightarrow \varphi(x, \omega) \quad \textbf{for all } x \in \mathbf{R}^n \qquad (2),$$

$$\varphi^{\omega}: \mathbf{R}^n \rightarrow \mathbf{R}^a,\ x \rightarrow \varphi(x, \omega) \quad \textbf{for all } \omega \in \Omega \qquad (3).$$

$\left\{\varphi_X;\ x \in \mathbf{R}^n\right\}$ is a stochastic process having an index set R^n and a projection φ^{ω} is a path in this stochastic process for each event $\omega \in \Omega$.

In the case of the recovery boiler, n=4 and a=14 (following the elimination of the variable "BL Back Pressure").

Because of the required ability to measure the projection φ_x for each $x \in R^n$, the projection φ_x is a random variable. Under suitable additional preconditions, expected values and higher moments can be considered. This access makes the step possible from stochastic models to deterministic optimization problems. In the case of a deterministic optimization problem, the target function can be set directly by means of

a variable, while the stochastic variable influences the target function but does not permit any deliberate setting.

DESCRIPTION OF THE OUTPUT VARIABLES

The process model M of the recovery boiler will be described as a function depending on the input variables and further random effects. In this case, let (Ω, S, P) be the above probability space. The process model M is then a projection which can be

measured by B^a x S - B^b:

$$M : \mathbf{R}^a \times \Omega \rightarrow \mathbf{R}^b \tag{4},$$

where b refers to the number of output variables.

Since the recovery boiler is subject to a cyclic drift over time (from cleaning phase to cleaning phase), a description using a time parameter is also conceivable. The output variables may be represented by projections ı that can be measured by B^n x S - B^b:

$$\psi : \mathbf{R}^n \times \Omega \rightarrow \mathbf{R}^b \tag{5},$$

$$(x, \omega) \rightarrow M(\varphi(x, \omega), \omega) \tag{6}.$$

If the respective projections onto the individual sets of the definition set are considered, then the following projections are obtained

$$\psi_x : \Omega \to \mathbf{R}^b,\ \omega \to \psi(x, \omega) \qquad \text{for all} \quad x \in \mathbf{R}^n \qquad (7),$$

$$\psi^\omega : \mathbf{R}^n \to \mathbf{R}^b,\ x \to \psi(x, \omega) \qquad \text{for all} \quad \omega \in \Omega \qquad (8).$$

$\left\{\psi_x;\ x \in \mathbf{R}^n\right\}$ is a stochastic process having an index set R^n, and the projection ψ^ω is a path in this stochastic process for each $\omega \in \Omega$.

In the recovery boiler, b=15.

The fact that, when defining ψ, no distinction is drawn between the events ω used, does not mean that there is any restriction, since Ω can be represented as a cartesian product of an Ω1 and an Ω2. The above representation therefore also comprises the model:

$$\psi : \mathbf{R}^n \times \Omega_1 \times \Omega_2 \to \mathbf{R}^b \qquad (9),$$

$$(x, \omega_1, \omega_2) \to M(\varphi(x, \omega_1), \omega_2) \qquad (10).$$

DESCRIPTION OF THE DATA SETS AVAILABLE

Using the descriptions in the two preceding sections, it is possible to combine the input variables and the output variables together to form measured variables Φ. Φ is a projection that can be measured by B^n x S - B^m, where m = a + b, and

$$\Phi : \mathbf{R}^n \times \Omega \to \mathbf{R}^m \qquad (11),$$

$$(x, \omega) \to \begin{pmatrix} \varphi(x, \omega) \\ \psi(x, \omega) \end{pmatrix} \qquad (12).$$

If the respective projections onto the individual sets of the definition set are considered again, then the following projections are obtained:

$$\Phi_x : \Omega \to \mathbf{R}^m,\ \omega \to \Phi(x, \omega) \quad \textbf{for all} \quad x \in \mathbf{R}^n \qquad (13),$$

$$\Phi^\omega : \mathbf{R}^n \to \mathbf{R}^m,\ x \to \Phi(x, \omega) \quad \textbf{for all} \quad \omega \in \Omega \qquad (14).$$

$\left\{\Phi_x;\ x \in \mathbf{R}^n\right\}$ is a stochastic process with an index set R^n and the projection Φ^ω is a path in this stochastic process for each $\omega \in \Omega$.

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For each chosen tuple x of actuating variables, a large number of implementations of Φ_x in the recovery boiler are determined and stored, that is to say for each $x_j \in R^n$, numerous implementations

$$\Phi_{jk} := \Phi\left(x_j, \omega_{jk}\right) \tag{15}$$

$$\textbf{with} \quad \omega_{jk} \in \Omega; \quad k = 1,2,\ldots,v_j;$$

$$v_j \in \mathbf{N}; \quad j = 1,2,\ldots,u; \quad u \in \mathbf{N}$$

are considered. The stored data sets Djk of the recovery boiler are therefore (n + m) tuples:

$$D_{jk} = \begin{pmatrix} x_j \\ \Phi_{jk} \end{pmatrix}, \qquad k = 1,2,\ldots,v_j; \quad j = 1,2,\ldots,u \tag{16}$$

Here, D_{j1k1} is stored before D_{j2k2} if

$$\left(j_1 < j_2\right) \vee \left(\left(j_1 = j_2\right) \wedge \left(k_1 < k_2\right)\right)$$

DATA COMPRESSION BY DIVIDING THE CLASSES OF PARAMETERS

Since, for each tuple x of actuating variables, there are generally a number of implementations of Φ_x, because of the complex stochastic properties of the process to

be considered, the first step in the statistical data analysis is obviously to divide the classes of parameters by forming arithmetic averages. In addition, obviously erroneous data sets are separated out. An obviously erroneous data set is, for example, a physically impossible measurement which cannot possibly occur in real terms, in particular on the basis of a setting which has been made.

Procedure:

1. Data sets in which the variable "BL Front Pressure" is not equal to the variable "BL Back Pressure" are screened out, since these two values must be equal according to the predefinition of the plant control system. The loss of data is very small.

2. The data sets are divided into classes in which the four setting parameters (PA, SA, TA, BL Front Pressure, see above) are successively constant over time, that is to say the jth class consists of the data sets $D_{j\bullet}$.

3. Classes in which there are fewer than 30 data sets are screened out, in order that transient processes do not have any great influence.

4. For each class, an arithmetic average $\overline{\Phi}j$ and an empirical standard deviation sj are determined for all the measured variables:

$$\overline{\Phi}_j = \frac{1}{v_j} \cdot \sum_{k=1}^{v_j} \Phi_{jk} \qquad (17),$$

$$s_j = \begin{pmatrix} \left(\dfrac{1}{v_j - 1} \cdot \displaystyle\sum_{k=1}^{v_j} \left(\Phi_{jk}^{(1)} - \overline{\Phi}_j^{(1)} \right)^2 \right)^{\frac{1}{2}} \\ \vdots \\ \left(\dfrac{1}{v_j - 1} \cdot \displaystyle\sum_{k=1}^{v_j} \left(\Phi_{jk}^{(m)} - \overline{\Phi}_j^{(m)} \right)^2 \right)^{\frac{1}{2}} \end{pmatrix} \qquad (18).$$

5. Classes in which the averages for the variables PA, SA, TA or BL Front Pressure are too far removed from the corresponding setting parameters are screened out. In these classes, therefore, the setting values could not be reached.

CHARACTERISTIC STATISTICAL VARIABLES FOR THE GIVEN CLASSES AND THEIR GRAPHICAL REPRESENTATION

In addition to the arithmetic averages and the empirical standard deviations which have been determined for the individual classes, a common standard deviation s is further determined in accordance with

$$s = \begin{pmatrix} \left(\frac{1}{v - 1} \cdot \sum_{j=1}^{u} \left(v_j - 1 \right) s_j^{(1)2} \right)^{\frac{1}{2}} \\ \vdots \\ \left(\frac{1}{v - 1} \cdot \sum_{j=1}^{u} \left(v_j - 1 \right) s_j^{(m)2} \right)^{\frac{1}{2}} \end{pmatrix} \qquad (19)$$

Here, u stands for the number of classes (205 here) and v for the sum of v_j, that is to say v is the number of all the measured values used (38,915 here).

Although other modifications and changes may be suggested by those skilled in the art, it is the intention of the inventors to embody within the patent warranted hereon all changes and modifications as reasonably and properly come within the scope of their contribution to the art.

Abstract of the Disclosure

A method and system for screening out empirically data collected from various steps of a technical process operating based on a first set of parameters, by utilizing a screening algorithm to reduce the size of the empirical data set, thus improving the modeling and revising of the technical process. The algorithm utilizes various classes associated with the empirical values and within each class performs an assessment with respect to preselected threshold values. The algorithm also performs an assessment with respect to another preselected threshold value, for the class as a whole.

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~~Description~~ SPECIFICATION

~~Method and arrangement for reducing a number of measured values of a technical system~~ TITLE

~~The~~ METHOD AND ARRANGEMENT FOR REDUCING A NUMBER OF MEASURED VALUES OF A TECHNICAL SYSTEM

BACKGROUND OF THE INVENTION

Field of the Invention

The present inventive method relates to a method and an arrangement for reducing a number of measured values of a technical system.

Description of the Related Art

A technical system, for example a process engineering plant, supplies a large quantity of measured values per unit time, using different measured-value pickups (sensors). In the course of a number of days or weeks, a quantity of data accumulates which requires a correspondingly high computational power to process it. If the measured values are to be used to adapt or reset the technical system, operations are often necessary whose complexity admits only some of the measured values. It is then a great disadvantage to select a specific number of measured values arbitrarily from the quantity of all measured values and to process them further, since measured values with low significance, for example measured values with a high degree of interference, have a considerable influence on the overall result and falsify the latter considerably.

SUMMARY OF THE INVENTION

The object of the invention is to specify a method and an arrangement for reducing measured values, it being ensured that the remaining measured values have a high significance with regard to their description of the technical system.

~~This object is achieved in accordance with the features of the independent patent claims. Developments of the invention emerge from the dependent claims.~~ In order to achieve the object, a method of reducing a number of measured values of a technical system is specified, ~~inwhich~~ **in which** the measured values are divided into classes in accordance with predefined criteria. The measured values in a class are assessed and those measured values whose assessment lies below a predefined first threshold value are screened out.

Screening out the measured values results in a reduction with regard to the number of measured values. A considerably reduced number of measured values is thus available for further processing. The further processing can be carried out with a lower computational outlay as compared with the non-reduced number of measured values.

~~One development consists in that~~ **In one embodiment,** the classes themselves are also assessed. In particular, a class whose assessment lies below a predefined second threshold value can be screened out. This results in an additional reduction in the number of measured values.

~~Another development consists in that~~ **In another embodiment,** one criterion for the division into classes consists in that, for each class, measured values relating to a predefinition of setting parameters of the technical system are determined. Typically, the technical system is set using a predefined number of setting parameters and after the setting has been carried out, there follows a (mostly time-delayed) reaction of the system to the setting parameters (transient response, transient process of the system). After the setting operation, a specific quantity of measured values which can be associated with the transient process are therefore picked up, measured values which are associated with the predefined set of setting parameters continuing to accumulate after the transient process has concluded (transition to steady-state operation). By adjusting the setting parameters, a new class is determined. All the measured values which respectively accumulate after an

adjustment to the setting parameters belong in their own ~~class. Another~~ **class. Another** development consists in that measured values within a class which can be associated with the respective transient process are screened out. In addition, erroneous measured values can be screened out. In many cases, the setting of large technical systems depends on long-term, steady-state operation. Measured values which relate to the transient process (of short duration in comparison with the steady-state operation after the transient process has concluded) are expediently screened out, since measured values for the steady-state operation are falsified by them. In particular within the context of modeling the technical system, the measured data about the steady-state behavior of the technical system are of interest.

One refinement **of this embodiment** consists in reducing the number of measured values in a class in that at least one representative value for the measured values in the class is determined. Such a representative value may be:

a) an average (e.g. a sliding average) of the measured values of the class,

b) a maximum value of the measured values of the class,

c) a minimum value of the measured values of the class,

d) a median.

In the case of variant (d), one advantage resides in the fact that it is always possible to determine a value which is actually present, while the average (a) does not itself occur as a value.

Depending on the application, a suitable selection for determining the representative value of a class may be made.

An entire class with measured values can be screened out if said class contains less than a predefined number of measured values.

Another refinement consists in that those measured values are screened out which differ from a predefinable value by more than a predefined threshold ~~value.The~~ **value.**

The predefinable value can be an average of all the measured values of the class or a measured value to be expected in response to the respective setting parameters of the technical system.

A development consists in that the measured values which are reduced in number are used for the simulation and/or the draft design of this or another technical system.

The draft design of the technical system can in this case comprise both adaptation and redrafting of this or another technical system.

In addition, within the context of the simulation, the behavior of the technical system can be checked by using the reduced number of measured values, with the objective of altering the system for developing a new system with altered predefinitions.

In addition, in order to achieve the object, an arrangement for reducing a number of measured values of a technical system is specified which has a processor unit, which processor unit is set up in such a way that the measured values can be divided into classes in accordance with predefined criteria. Measured values in a class can be assessed, measured values whose assessment lies below a predefined first threshold value are screened out.

This arrangement is particularly suitable for carrying out the method according to the invention or one of its developments explained above.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig ~~Exemplary embodiments of the invention will be illustrated and explained below using the drawing, in whichFig~~. 1 shows a block diagram which contains steps in a method for reducing measured values~~;~~.

Fig. 2 shows a schematic sketch of a recovery boiler~~;~~.

Figs. 3 -**through** 5 show input variables, actuating variables and outward variables of the recovery boiler.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Fig. 1 shows a block diagram which contains steps in a method of reducing measured values. In a first step 101, the measured values are divided into classes. In particular, the division into classes is carried out with the effect that all the measured values which belong to one set of setting parameters are combined in one class. To this extent, each alteration to the setting parameters of the technical system found a new class. In particular, altering the setting parameters is associated with a transient process of the technical system, this process, as opposed to a steady-state behavior, containing extreme fluctuations in the measured values. In a step 102, individual measured values within one class are screened out. These may be, for example, erroneous measured values, that is to say measured values which exhibit a high deviation with respect to the other measured values or an average of the measured values or measured values from the transient process. There are a number of possible ways of screening out individual measured values within a class:

1. Measured values which are too poor (based on a predefined comparative value);
2. Measured values which belong to a transient process;
3. Measured values which are erroneous;

4. Determining a representative measured value as a representative for a plurality of measured values, in that the representative measured value is determined as an average of the measured values in a class or as a maximum value or a minimum value of these measured ~~values.Measured~~ **values.**

Measured values of this type are preferably not taken into account; they are removed from the respective class. This results in a considerable reduction in the number of measured values. In a step 103, individual classes are screened out. One criterion for screening out an entire class consists in that the class contains less than a predefined number of measured values. In a step 104, the measured values reduced in number are used for further processing. Further processing is, in particular, a simulation and/or a draft design of the technical system.

Fig. 2 shows a schematic sketch of a recovery boiler. In the following text, by using the example of a "recovery boiler", an exemplary embodiment of the method described above will be illustrated.

In the paper and pulp industry, various chemicals and also heat and electrical power are needed for the digestion of pulp. With the aid of the recovery boiler, the chemicals used and additional thermal energy may be recovered from a thickened waste process liquor (black liquor). A measure of the recovery of the chemicals is of critical importance for the economy of the overall plant.

The black liquor is burned in a char bed 201. In the process, an alkaline melt is produced and flows away via a line 202. In further process steps, the chemicals used

are recovered from the constituents of the alkaline melt. Heat of combustion which is released is used to generate steam. The combustion of the waste liquor and therefore the recovery of the chemicals begins with the atomization of the black liquor via atomizer nozzles 204 into a combustion chamber 203. As they fall through the hot flue gas, particles of the atomized black liquor are dried. The dried liquor particles fall onto the char bed 201, first combustion ~~andchemical~~ **and chemical** reduction taking place. Volatile constituents and reaction products pass into an oxidation zone, in which oxidizing reactions proceed and in which the combustion is completed.

Important objectives for the control of the recovery boiler are the steam production in order to obtain power, compliance with emission values from environmental points of view and the efficiency of the chemical reduction.

The combustion operation, and therefore the objectives, are controlled in particular by the supply of air at three levels (primary air (PA), secondary air (SA), tertiary air (TA)). The overall process is subject to numerous influences, which have to be taken into account during the modeling:

a) the measurement of the variables is subject to fluctuations which are often extreme;

b) influencing variables which are not measured and cannot be measured exist;

c) at each alteration to the settable parameters transient processes occur;

d) the technical plant becomes soiled and is cleaned at predefined intervals, which has the effect of a drift over time in each case in the system behavior.

The measured variables of the overall process are subdivided into input variables (cf. Fig. 3) and output variables (cf. Fig. 5). Measured variables are stored every minute. Four of the input variables are simultaneously also actuating variables (also: settable parameters; cf. Fig. 4). The actuating variables are to be viewed substantially as free parameters of the overall process which can be set independently of one another. Some of the ~~otherinput~~ **other input** variables are more or less dependent on the actuating variables. According to one predefinition, the variables "BL Front Pressure" and "BL Back Pressure" are always to be regulated equally in the recovery boiler. The four actuating variables (cf. Fig. 4) are preferably to be stored as actuating variables (with the desired, preset value) and as input variables (with the measured, actual value).

In the recovery boiler, one problem consists in the fact that, depending on the settable parameters, specific objectives, which are defined via measured variables, have to be met. Here, a three-stage procedure is selected in order to solve the problem:

1. The objectives to be considered are modeled by means of stochastic methods, these models being updated by means of new measurements (data-driven, empirical modeling). In this case, it is expedient to use not just a single model

but global models for the identification of interesting areas in a parameter space determined by the objectives, and to use local models for the exact calculation of optimum operating points. The models used are assessed by means of quality measures.

2. If the models considered are not sufficiently accurate because of the state of the data (quality measure), new operating points are deliberately evaluated in order to improve the model (experimental design). In addition, by using global stochastic optimization methods with regard to the objectives, attractive regions are identified on the basis of the current global model.

3. For the local optimization, local models are constructed, and the data sets which are available

are, if appropriate, deliberately expanded (experimental ~~design).The~~ **design).**

The objectives are physical/technical or economic criteria which, as a rule, have to meet boundary conditions and/or safety conditions. It is often the case that a number of these criteria have to be considered at the same time. A stochastic model can be used in particular for the purpose of simulating the objectives to be optimized and their dependence on the parameters to be set in the computer. This is necessary when measurements are very costly or very time-consuming. In the case of safety requirements, possible hazardous situations can be avoided.

In the case of the recovery boiler, on-line optimization, which is based on a plurality of items of data, is necessary, since the physical/chemical processes cannot be modeled quantitatively with sufficient accuracy and because the behavior of the plant is subject to fluctuations in the course of operation. The knowledge about this behavior must continually be expanded by means of the deliberate selection of new operating points. Therefore, within the context of on-line optimization, the above-described three-stage procedure of stochastic modeling at mathematical optimization is to be recommended.

DESCRIPTION OF THE INPUT VARIABLES

The a input variables ($a \in N$, N: set of natural numbers) generally depend on n actuating variables $n \in N$ and on random effects. They can be described as follows:

Let (Ω, S, P) be a probability space and B^v be a Borel σ-algebra over ~~RV~~ <u>**R^v**</u> (R: set of real numbers) for each $v \in N$. The input variables are represented by a projection φ which can be measured via $B^n \times S - B^a$:

$\varphi: R^n \times \Omega \rightarrow R^a$ ~~(1).The~~<u>**(1). The**</u> definition set of the projection φ is a cartesian product of two sets. If one considers the respective projections onto the individual sets, then the following projections are obtained:

$$\varphi_x: \Omega \rightarrow \mathbf{R}^a,\ \omega \rightarrow \varphi(x, \omega) \quad \text{for all } x \in \mathbf{R}^n \qquad (2),$$

$$\varphi^{\omega}: \mathbf{R}^n \rightarrow \mathbf{R}^a,\ x \rightarrow \varphi(x, \omega) \quad \text{for all } \omega \in \Omega \qquad (3).$$

$\{\varphi_x;\ x \in \mathbf{R}^n\}$ is a stochastic process having an index set R^n and a projection φ^ω is a path in this stochastic process for each event $\omega \in \Omega$.

In the case of the recovery boiler, n=4 and a=14 (following the elimination of the variable "BL Back Pressure").

Because of the required ability to measure the projection φ_x for each $x \in R^n$, the projection φ_x is a random variable. Under suitable additional preconditions, expected values and higher moments can be considered. This access makes the step possible from stochastic models to deterministic optimization problems. In the case of a deterministic optimization problem, the target function can be set directly by means of a variable, while the stochastic variable influences the target function but does not permit any deliberate setting.

DESCRIPTION OF THE OUTPUT VARIABLES

The process model M of the recovery boiler will be described as a function depending on the input variables and further random effects. In this case, let (Ω, S, P) be the above probability space. The process model M is then a projection which can be

measured by B^a x S **- B^b:** ~~-Bb:~~

$$M : \mathbf{R}^a \times \Omega \rightarrow \mathbf{R}^b \qquad (4),$$

where b refers to the number of output variables.

Since the recovery boiler is subject to a cyclic drift over time (from cleaning phase to cleaning phase), a description using a time parameter is also conceivable. The output variables may be represented by projections ı that can be measured by B^n x S - B^b:

$$\psi : \mathbf{R}^n \times \Omega \rightarrow \mathbf{R}^b \qquad (5),$$

$$(x, \omega) \rightarrow M(\varphi(x, \omega), \omega) \qquad (6).$$

If the respective projections onto the individual sets of the definition set are considered, then the following projections are obtained

$$\psi_x : \Omega \rightarrow \mathbf{R}^b,\ \omega \rightarrow \psi(x, \omega) \quad \textbf{for all} \ x \in \mathbf{R}^n \qquad (7),$$

$$\psi^\omega : \mathbf{R}^n \rightarrow \mathbf{R}^b,\ x \rightarrow \psi(x, \omega) \quad \textbf{for all} \ \omega \in \Omega \qquad (8).$$

$\left\{\psi_x ;\ x \in \mathbf{R}^n\right\}$ is a stochastic process having an index set R^n, and the projection ~~tω~~ $\underline{\psi^\omega}$ is a path in this stochastic process for each $\omega \in \Omega$.

In the recovery boiler, b=15.

The fact that, when defining ψ, no distinction is drawn between the events ω used, does not mean that there is any restriction, since Ω can be represented as a cartesian product of an $\Omega 1$ and an $\Omega 2$. The above representation therefore also comprises the model:

$$\psi : \mathbf{R}^n \times \Omega_1 \times \Omega_2 \rightarrow \mathbf{R}^b \qquad (9),$$

$$(x, \omega_1, \omega_2) \rightarrow M(\varphi(x, \omega_1), \omega_2) \qquad (10).$$

DESCRIPTION OF THE DATA SETS AVAILABLE

Using the descriptions in the two preceding sections, it is possible to combine the input variables and the output variables together to form measured variables Φ. Φ is a projection that can be measured by B^n x S - B^m, where m = a + b, and

$$\Phi : \mathbf{R}^n \times \Omega \rightarrow \mathbf{R}^m \qquad (11),$$

$$(x, \omega) \rightarrow \begin{pmatrix} \varphi(x, \omega) \\ \psi(x, \omega) \end{pmatrix} \qquad (12).$$

If the respective projections onto the individual sets of the definition set are considered again, then the following projections are obtained:

$$\Phi_X : \Omega \rightarrow \mathbf{R}^m, \ \omega \rightarrow \Phi(x, \omega) \qquad \textbf{for all} \ \ x \in \mathbf{R}^n \qquad (13),$$

$$\Phi^\omega : \mathbf{R}^n \rightarrow \mathbf{R}^m, \ x \rightarrow \Phi(x, \omega) \qquad \textbf{for all} \ \ \omega \in \Omega \qquad (14).$$

$\left\{\Phi_X;\ x \in \mathbf{R}^n\right\}$ is a stochastic process with an index set R^n

and the projection Φ^ω is a path in this stochastic process for each $\omega \in \Omega$.

For each chosen tuple x of actuating variables, a large number of implementations of Φ_x in the recovery boiler are determined and stored, that is to say for each $x_j \in R^n$, numerous implementations

$$\Phi_{jk} := \Phi\left(x_j, \omega_{jk}\right) \tag{15}$$

$$\textbf{with} \quad \omega_{jk} \in \Omega; \; k = 1,2,\ldots,v_j;$$

$$v_j \in \mathbf{N}; \; j = 1,2,\ldots,u; \; u \in \mathbf{N}$$

are considered. The stored data sets Djk of the recovery boiler are therefore (n + m) tuples:

$$D_{jk} = \begin{pmatrix} x_j \\ \Phi_{jk} \end{pmatrix}, \quad k = 1,2,\ldots,v_j; \; j = 1,2,\ldots,u \tag{16}$$

Here, D_{j1k1} is stored before D_{j2k2} if

$$(j_1 < j_2) \vee \left((j_1 = j_2) \wedge (k_1 < k_2)\right)$$

DATA COMPRESSION BY DIVIDING THE CLASSES OF PARAMETERS

Since, for each tuple x of actuating variables, there are generally a number of implementations of Φ_x, because of the complex stochastic properties of the process to

be considered, the first step in the statistical data analysis is obviously to divide the classes of parameters by forming arithmetic averages. In addition, obviously erroneous data sets are separated out. An obviously erroneous data set is, for example, a physically impossible measurement which cannot possibly occur in real terms, in particular on the basis of a setting which has been made.

Procedure:

1. Data sets in which the variable "BL Front Pressure" is not equal to the variable "BL Back Pressure" are screened out, since these two values must be equal according to the predefinition of the plant control system. The loss of data is very small.
2. The data sets are divided into classes in which the four setting parameters (PA, SA, TA, BL Front Pressure, see above) are successively constant over time, that is to say the jth class consists of the data sets $D_{j\bullet}$.
3. Classes in which there are fewer than 30 data sets are screened out, in order that transient processes do not have any great influence.
4. For each class, an arithmetic average $\overline{\Phi}j$ and an empirical standard deviation sj are determined for all the measured variables:

$$\overline{\Phi}_j = \frac{1}{v_j} \cdot \sum_{k=1}^{v_j} \Phi_{jk} \qquad (17),$$

$$s_j = \begin{pmatrix} \left(\frac{1}{v_j - 1} \cdot \sum_{k=1}^{v_j} \left(\Phi_{jk}^{(1)} - \overline{\Phi}_j^{(1)} \right)^2 \right)^{\frac{1}{2}} \\ \vdots \\ \left(\frac{1}{v_j - 1} \cdot \sum_{k=1}^{v_j} \left(\Phi_{jk}^{(m)} - \overline{\Phi}_j^{(m)} \right)^2 \right)^{\frac{1}{2}} \end{pmatrix} \qquad (18).$$

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5. Classes in which the averages for the variables PA, SA, TA or BL Front Pressure are too far removed from the corresponding setting parameters are screened out. In these classes, therefore, the setting values could not be ~~reached.CHARACTERISTIC~~ **reached.**

CHARACTERISTIC STATISTICAL VARIABLES FOR THE GIVEN CLASSES AND THEIR GRAPHICAL REPRESENTATION

In addition to the arithmetic averages and the empirical standard deviations which have been determined for the individual classes, a common standard deviation s is further determined in accordance with

$$s = \begin{pmatrix} \left(\frac{1}{v-1} \cdot \sum_{j=1}^{u} \left(v_j - 1\right) s_j^{(1)2} \right)^{\frac{1}{2}} \\ \vdots \\ \left(\frac{1}{v-1} \cdot \sum_{j=1}^{u} \left(v_j - 1\right) s_j^{(m)2} \right)^{\frac{1}{2}} \end{pmatrix} \qquad (19)$$

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Here, u stands for the number of classes (205 here) and v for the sum of v_j, that is to say v is the number of all the measured values used (38,915 here).

~~Abstract~~ **Although other modifications and changes may be suggested by those skilled in the art, it is the intention of the inventors to embody within the patent warranted hereon all changes and modifications as reasonably and properly come within the scope of their contribution to the art.**

~~Method and arrangement for reducing a number of measured values of a technical system~~ Abstract of the Disclosure

~~A method of reducing a number of measured values of the technical system is specified in which the measured values are divided into classes in accordance with predefined criteria. The measured values in a class are assessed and those measured values whose assessment lies below a predefined first threshold value are screened out~~ A method and system for screening out empirically data collected from various steps of a technical process operating based on a first set of parameters, by utilizing a screening algorithm to reduce the size of the empirical data set, thus improving the modeling and revising of the technical process. The algorithm utilizes various classes associated with the empirical values and within each class performs an assessment with respect to preselected threshold values. The algorithm also performs an assessment with respect to another preselected threshold value, for the class as a whole.

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Description

Method and arrangement for reducing a number of measured values of a technical system

The method relates to a method and an arrangement for reducing a number of measured values of a technical system.

A technical system, for example a process engineering plant, supplies a large quantity of measured values per unit time, using different measured-value pickups (sensors). In the course of a number of days or weeks, a quantity of data accumulates which requires a correspondingly high computational power to process it. If the measured values are to be used to adapt or reset the technical system, operations are often necessary whose complexity admits only some of the measured values. It is then a great disadvantage to select a specific number of measured values arbitrarily from the quantity of all measured values and to process them further, since measured values with low significance, for example measured values with a high degree of interference, have a considerable influence on the overall result and falsify the latter considerably.

The object of the invention is to specify a method and an arrangement for reducing measured values, it being ensured that the remaining measured values have a high significance with regard to their description of the technical system.

This object is achieved in accordance with the features of the independent patent claims. Developments of the invention emerge from the dependent claims.

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In order to achieve the object, a method of reducing a number of measured values of a technical system is specified, in

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which the measured values are divided into classes in accordance with predefined criteria. The measured values in a class are assessed and those measured values whose assessment lies below a predefined first threshold value are screened out.

Screening out the measured values results in a reduction with regard to the number of measured values. A considerably reduced number of measured values is thus available for further processing. The further processing can be carried out with a lower computational outlay as compared with the non-reduced number of measured values.

One development consists in that the classes themselves are also assessed. In particular, a class whose assessment lies below a predefined second threshold value can be screened out. This results in an additional reduction in the number of measured values.

Another development consists in that one criterion for the division into classes consists in that, for each class, measured values relating to a predefinition of setting parameters of the technical system are determined. Typically, the technical system is set using a predefined number of setting parameters and after the setting has been carried out, there follows a (mostly time-delayed) reaction of the system to the setting parameters (transient response, transient process of the system). After the setting operation, a specific quantity of measured values which can be associated with the transient process are therefore picked up, measured values which are associated with the predefined set of setting parameters continuing to accumulate after the transient process has concluded (transition to steady-state operation). By adjusting the setting parameters, a new class is determined. All the measured values which respectively accumulate after an

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adjustment to the setting parameters belong in their own class.

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Another development consists in that measured values within a class which can be associated with the respective transient process are screened out. In addition, erroneous measured values can be screened out. In many cases, the setting of large technical systems depends on long-term, steady-state operation. Measured values which relate to the transient process (of short duration in comparison with the steady-state operation after the transient process has concluded) are expediently screened out, since measured values for the steady-state operation are falsified by them. In particular within the context of modeling the technical system, the measured data about the steady-state behavior of the technical system are of interest.

One refinement consists in reducing the number of measured values in a class in that at least one representative value for the measured values in the class is determined. Such a representative value may be:

a) an average (e.g. a sliding average) of the measured values of the class,
b) a maximum value of the measured values of the class,
c) a minimum value of the measured values of the class,
d) a median.

In the case of variant d), one advantage resides in the fact that it is always possible to determine a value which is actually present, while the average a) does not itself occur as a value.

Depending on the application, a suitable selection for determining the representative value of a class may be made.

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An entire class with measured values can be screened out if said class contains less than a predefined number of measured values.

Another refinement consists in that those measured values are screened out which differ from a predefinable value by more than a predefined threshold value.

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The predefinable value can be an average of all the measured values of the class or a measured value to be expected in response to the respective setting parameters of the technical system.

A development consists in that the measured values which are reduced in number are used for the simulation and/or the draft design of this or another technical system.

The draft design of the technical system can in this case comprise both adaptation and redrafting of this or another technical system.

In addition, within the context of the simulation, the behavior of the technical system can be checked by using the reduced number of measured values, with the objective of altering the system for developing a new system with altered predefinitions.

In addition, in order to achieve the object, an arrangement for reducing a number of measured values of a technical system is specified which has a processor unit, which processor unit is set up in such a way that the measured values can be divided into classes in accordance with predefined criteria. Measured values in a class can be assessed, measured values whose assessment lies below a predefined first threshold value are screened out.

This arrangement is particularly suitable for carrying out the method according to the invention or one of its developments explained above.

Exemplary embodiments of the invention will be illustrated and explained below using the drawing, in which

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Fig. 1 shows a block diagram which contains steps in a method for reducing measured values;

Fig. 2 shows a schematic sketch of a recovery boiler;

Figs. 3-5 show input variables, actuating variables and outward variables of the recovery boiler.

Fig. 1 shows a block diagram which contains steps in a method of reducing measured values. In a first step 101, the measured values are divided into classes. In particular, the division into classes is carried out with the effect that all the measured values which belong to one set of setting parameters are combined in one class. To this extent, each alteration to the setting parameters of the technical system found a new class. In particular, altering the setting parameters is associated with a transient process of the technical system, this process, as opposed to a steady-state behavior, containing extreme fluctuations in the measured values. In a step 102, individual measured values within one class are screened out. These may be, for example, erroneous measured values, that is to say measured values which exhibit a high deviation with respect to the other measured values or an average of the measured values or measured values from the transient process. There are a number of possible ways of screening out individual measured values within a class:

1. Measured values which are too poor (based on a predefined comparative value);
2. Measured values which belong to a transient process;
3. Measured values which are erroneous;
4. Determining a representative measured value as a representative for a plurality of measured values, in that the representative measured value is determined as an average of the

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measured values in a class or as a maximum value or a minimum value of these measured values.

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Measured values of this type are preferably not taken into account; they are removed from the respective class. This results in a considerable reduction in the number of measured values. In a step 103, individual classes are screened out. One criterion for screening out an entire class consists in that the class contains less than a predefined number of measured values. In a step 104, the measured values reduced in number are used for further processing. Further processing is, in particular, a simulation and/or a draft design of the technical system.

Fig. 2 shows a schematic sketch of a recovery boiler. In the following text, by using the example of a "recovery boiler", an exemplary embodiment of the method described above will be illustrated.

In the paper and pulp industry, various chemicals and also heat and electrical power are needed for the digestion of pulp. With the aid of the recovery boiler, the chemicals used and additional thermal energy may be recovered from a thickened waste process liquor (black liquor). A measure of the recovery of the chemicals is of critical importance for the economy of the overall plant.

The black liquor is burned in a char bed 201. In the process, an alkaline melt is produced and flows away via a line 202. In further process steps, the chemicals used are recovered from the constituents of the alkaline melt. Heat of combustion which is released is used to generate steam. The combustion of the waste liquor and therefore the recovery of the chemicals begins with the atomization of the black liquor via atomizer nozzles 204 into a combustion chamber 203. As they fall through the hot flue gas, particles of the atomized black liquor are dried. The dried liquor particles fall onto the char bed 201, first combustion and

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chemical reduction taking place. Volatile constituents and reaction products pass into an oxidation zone, in which oxidizing reactions proceed and in which the combustion is completed.

Important objectives for the control of the recovery boiler are the steam production in order to obtain power, compliance with emission values from environmental points of view and the efficiency of the chemical reduction.

The combustion operation, and therefore the objectives, are controlled in particular by the supply of air at three levels (primary air (PA), secondary air (SA), tertiary air (TA)). The overall process is subject to numerous influences, which have to be taken into account during the modeling:

a) the measurement of the variables is subject to fluctuations which are often extreme;
b) influencing variables which are not measured and cannot be measured exist;
c) at each alteration to the settable parameters transient processes occur;
d) the technical plant becomes soiled and is cleaned at predefined intervals, which has the effect of a drift over time in each case in the system behavior.

The measured variables of the overall process are subdivided into input variables (cf. Fig. 3) and output variables (cf. Fig. 5). Measured variables are stored every minute. Four of the input variables are simultaneously also actuating variables (also: settable parameters; cf. Fig. 4). The actuating variables are to be viewed substantially as free parameters of the overall process which can be set independently of one another. Some of the other

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input variables are more or less dependent on the actuating variables. According to one predefinition, the variables "BL Front Pressure" and "BL Back Pressure" are always to be regulated equally in the recovery boiler. The four actuating variables (cf. Fig. 4) are preferably to be stored as actuating variables (with the desired, preset value) and as input variables (with the measured, actual value).

In the recovery boiler, one problem consists in the fact that, depending on the settable parameters, specific objectives, which are defined via measured variables, have to be met. Here, a three-stage procedure is selected in order to solve the problem:

1. The objectives to be considered are modeled by means of stochastic methods, these models being updated by means of new measurements (data-driven, empirical modeling). In this case, it is expedient to use not just a single model but global models for the identification of interesting areas in a parameter space determined by the objectives, and to use local models for the exact calculation of optimum operating points. The models used are assessed by means of quality measures.

2. If the models considered are not sufficiently accurate because of the state of the data (quality measure), new operating points are deliberately evaluated in order to improve the model (experimental design). In addition, by using global stochastic optimization methods with regard to the objectives, attractive regions are identified on the basis of the current global model.

3. For the local optimization, local models are constructed, and the data sets which are available

are, if appropriate, deliberately expanded (experimental design).

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The objectives are physical/technical or economic criteria which, as a rule, have to meet boundary conditions and/or safety conditions. It is often the case that a number of these criteria have to be considered at the same time. A stochastic model can be used in particular for the purpose of simulating the objectives to be optimized and their dependence on the parameters to be set in the computer. This is necessary when measurements are very costly or very time-consuming. In the case of safety requirements, possible hazardous situations can be avoided.

In the case of the recovery boiler, on-line optimization, which is based on a plurality of items of data, is necessary, since the physical/chemical processes cannot be modeled quantitatively with sufficient accuracy and because the behavior of the plant is subject to fluctuations in the course of operation. The knowledge about this behavior must continually be expanded by means of the deliberate selection of new operating points. Therefore, within the context of on-line optimization, the above-described three-stage procedure of stochastic modeling at mathematical optimization is to be recommended.

DESCRIPTION OF THE INPUT VARIABLES

The a input variables ($a \in \mathbf{N}$, $\mathbf{N}$: set of natural numbers) generally depend on n actuating variables $n \in \mathbf{N}$ and on random effects. They can be described as follows:

Let $(\Omega, \boldsymbol{S}, \boldsymbol{P})$ be a probability space and $\boldsymbol{B}^v$ be a Borel σ-algebra over $\mathbf{R}^v$ ($\mathbf{R}$: set of real numbers) for each $v \in \mathbf{N}$. The input variables are represented by a projection φ which can be measured via $\boldsymbol{B}^n \times \boldsymbol{S} - \boldsymbol{B}^a$:

$$\varphi: \mathbf{R}^n \times \Omega \rightarrow \mathbf{R}^a \qquad (1).$$

The definition set of the projection φ is a cartesian product of two sets. If one considers the respective projections onto the individual sets, then the following projections are obtained:

$$\varphi_X : \Omega \to \mathbf{R}^a,\ \omega \to \varphi(x,\omega) \qquad \textbf{for all } x \in \mathbf{R}^n \qquad (2),$$

$$\varphi^{\omega} : \mathbf{R}^n \to \mathbf{R}^a,\ x \to \varphi(x,\omega) \qquad \textbf{for all } \omega \in \Omega \qquad (3).$$

$\{\varphi_X;\ x \in \mathbf{R}^n\}$ is a stochastic process having an index set $\mathbf{R}^n$ and a projection φ^{ω} is a path in this stochastic process for each event $\omega \in \Omega$.

In the case of the recovery boiler, n=4 and a=14 (following the elimination of the variable "BL Back Pressure").

Because of the required ability to measure the projection φ_x for each $x \in \mathbf{R}^n$, the projection φ_x is a random variable. Under suitable additional preconditions, expected values and higher moments can be considered. This access makes the step possible from stochastic models to deterministic optimization problems. In the case of a deterministic optimization problem, the target function can be set directly by means of a variable, while the stochastic variable influences the target function but does not permit any deliberate setting.

DESCRIPTION OF THE OUTPUT VARIABLES

The process model M of the recovery boiler will be described as a function depending on the input variables and further random effects. In this case, let $(\Omega, \boldsymbol{S}, \boldsymbol{P})$ be the above probability space. The process model M is then a projection which can be measured by $\boldsymbol{B}^a \times \boldsymbol{S} - \boldsymbol{B}^b$:

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$$M : \mathbf{R}^a \times \Omega \to \mathbf{R}^b \qquad (4),$$

where b refers to the number of output variables.

Since the recovery boiler is subject to a cyclic drift over time (from cleaning phase to cleaning phase), a description using a time parameter is also conceivable. The output variables may be represented by projections ψ that can be measured by $\mathbf{B}^n$ x $\mathbf{S}$ - $\mathbf{B}^b$:

$$\psi : \mathbf{R}^n \times \Omega \to \mathbf{R}^b \qquad (5),$$

$$(x, \omega) \to M(\varphi(x, \omega), \omega) \qquad (6).$$

If the respective projections onto the individual sets of the definition set are considered, then the following projections are obtained

$$\psi_x : \Omega \to \mathbf{R}^b,\ \omega \to \psi(x, \omega) \quad \textbf{for all} \quad x \in \mathbf{R}^n \qquad (7),$$

$$\psi^\omega : \mathbf{R}^n \to \mathbf{R}^b,\ x \to \psi(x, \omega) \quad \textbf{for all} \quad \omega \in \Omega \qquad (8).$$

$\left\{\psi_x;\ x \in \mathbf{R}^n\right\}$ is a stochastic process having an index set $\mathbf{R}^n$, and the projection ψ^ω is a path in this stochastic process for each $\omega \in \Omega$.

In the recovery boiler, b=15.

The fact that, when defining ψ, no distinction is drawn between the events ω used, does not mean that there is any restriction, since Ω can be represented as a cartesian product of an Ω_1 and an Ω_2. The above representation therefore also comprises the model:

$$\psi : \mathbf{R}^n \times \Omega_1 \times \Omega_2 \rightarrow \mathbf{R}^b \qquad (9),$$

$$(x, \omega_1, \omega_2) \rightarrow M(\varphi(x, \omega_1), \omega_2) \qquad (10).$$

DESCRIPTION OF THE DATA SETS AVAILABLE

Using the descriptions in the two preceding sections, it is possible to combine the input variables and the output variables together to form measured variables Φ. Φ is a projection that can be measured by $\boldsymbol{B}^n$ x $\boldsymbol{S}$ - $\boldsymbol{B}^m$, where m = a + b, and

$$\Phi : \mathbf{R}^n \times \Omega \rightarrow \mathbf{R}^m \qquad (11),$$

$$(x, \omega) \rightarrow \begin{pmatrix} \varphi(x, \omega) \\ \psi(x, \omega) \end{pmatrix} \qquad (12).$$

If the respective projections onto the individual sets of the definition set are considered again, then the following projections are obtained:

$$\Phi_x : \Omega \rightarrow \mathbf{R}^m,\ \omega \rightarrow \Phi(x, \omega) \quad \textbf{for all} \quad x \in \mathbf{R}^n \qquad (13),$$

$$\Phi^\omega : \mathbf{R}^n \rightarrow \mathbf{R}^m,\ x \rightarrow \Phi(x, \omega) \quad \textbf{for all} \quad \omega \in \Omega \qquad (14).$$

$\{\Phi_x;\ x \in \mathbf{R}^n\}$ is a stochastic process with an index set $\mathbf{R}^n$ and the projection Φ^ω is a path in this stochastic process for each $\omega \in \Omega$.

For each chosen tuple x of actuating variables, a large number of implementations of Φ_x in the recovery boiler are determined and stored, that is to say for each $x_j \in \mathbf{R}^n$, numerous implementations

$$\Phi_{jk} := \Phi(x_j, \omega_{jk}) \tag{15}$$

$$\text{with} \quad \omega_{jk} \in \Omega;\ k = 1,2,\ldots,v_j;$$

$$v_j \in \mathbf{N};\ j = 1,2,\ldots,u;\ u \in \mathbf{N}$$

are considered. The stored data sets D_{jk} of the recovery boiler are therefore (n + m) tuples:

$$D_{jk} = \begin{pmatrix} x_j \\ \Phi_{jk} \end{pmatrix}, \quad k = 1,2,\ldots,v_j;\ j = 1,2,\ldots,u \tag{16}$$

Here, D_{j1k1} is stored before D_{j2k2} if

$$(j_1 < j_2) \vee ((j_1 = j_2) \wedge (k_1 < k_2))$$

DATA COMPRESSION BY DIVIDING THE CLASSES OF PARAMETERS

Since, for each tuple x of actuating variables, there are generally a number of implementations of Φ_x, because of the complex stochastic properties of the process to be considered, the first step in the statistical data analysis is obviously to divide the classes of parameters by forming arithmetic averages. In addition, obviously erroneous data sets are separated out. An obviously erroneous data set is, for example, a physically impossible measurement which cannot possibly occur in real terms, in particular on the basis of a setting which has been made.

Procedure:

1. Data sets in which the variable "BL Front Pressure" is not equal to the variable "BL Back Pressure" are

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screened out, since these two values must be equal according to the predefinition of the plant control system. The loss of data is very small.

2. The data sets are divided into classes in which the four setting parameters (PA, SA, TA, BL Front Pressure, see above) are successively constant over time, that is to say the jth class consists of the data sets $D_{j\bullet}$.

3. Classes in which there are fewer than 30 data sets are screened out, in order that transient processes do not have any great influence.

4. For each class, an arithmetic average $\overline{\Phi}j$ and an empirical standard deviation sj are determined for all the measured variables:

$$\overline{\Phi}_j = \frac{1}{v_j} \cdot \sum_{k=1}^{v_j} \Phi_{jk} \qquad (17),$$

$$s_j = \begin{pmatrix} \left(\frac{1}{v_j - 1} \cdot \sum_{k=1}^{v_j} \left(\Phi_{jk}^{(1)} - \overline{\Phi}_j^{(1)} \right)^2 \right)^{\frac{1}{2}} \\ \vdots \\ \left(\frac{1}{v_j - 1} \cdot \sum_{k=1}^{v_j} \left(\Phi_{jk}^{(m)} - \overline{\Phi}_j^{(m)} \right)^2 \right)^{\frac{1}{2}} \end{pmatrix} \qquad (18).$$

5. Classes in which the averages for the variables PA, SA, TA or BL Front Pressure are too far removed from the corresponding setting parameters are screened out. In these classes, therefore, the setting values could not be reached.

CHARACTERISTIC STATISTICAL VARIABLES FOR THE GIVEN CLASSES AND THEIR GRAPHICAL REPRESENTATION

In addition to the arithmetic averages and the empirical standard deviations which have been determined for the individual classes, a common standard deviation s is further determined in accordance with

$$s = \begin{pmatrix} \left(\frac{1}{v-1} \cdot \sum_{j=1}^{u} \left(v_j - 1\right) s_j^{(1)^2}\right)^{\frac{1}{2}} \\ \vdots \\ \left(\frac{1}{v-1} \cdot \sum_{j=1}^{u} \left(v_j - 1\right) s_j^{(m)^2}\right)^{\frac{1}{2}} \end{pmatrix} \qquad (19)$$

Here, u stands for the number of classes (205 here) and v for the sum of v_j, that is to say v is the number of all the measured values used (38,915 here).

Patent claims

1. A method of reducing a number of measured variables of a technical system,
   a) in which the measured values are divided into classes in accordance with predefined criteria;
   b) in which the measured values in a class are assessed and measured values whose assessment lies below a predefined first threshold value are screened out;
   c) in which the classes are assessed and a class for which the assessment lies below a predefined second threshold value is screened out.

2. The method as claimed in one of the preceding claims, in which one criterion for the division into classes consists in that, for each class, measured values relating to a predefinition of setting parameters of the technical system are determined.

3. The method as claimed in one of the preceding claims, in which, in one class, measured values relating to a transient process and/or erroneous measured values are determined and screened out.

4. The method as claimed in one of the preceding claims, in which, in a class, the number of measured values is reduced in that at least one representative value for the measured values in the class is determined.

5. The method as claimed in claim 4, in which the representative value is determined as
   a) an average of the measured values in the class, or
   b) a maximum value or a minimum value of the measured values in the class;

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c) a median.

6. The method as claimed in one of the preceding claims, in which a class which has fewer than a predefined number of measured values is screened out.

7. The method as claimed in one of the preceding claims, in which, in a class, those measured values which differ from a predefinable value by more than a predefinable threshold value are screened out.

8. The method as claimed in one of the preceding claims, in which the reduced measured values are used for the simulation and/or for the draft design of the technical system.

9. An arrangement for reducing a number of measured values of a technical system,
having a processor unit which is set up in such a way that
  a) the measured values are divided into classes in accordance with predefined criteria;
  b) measured values in a class can be assessed and measured values whose assessment lies below a predefined first threshold value are screened out;
  c) the classes are assessed and a class for which the assessment lies below a predefined second threshold value is screened out.

10. The arrangement as claimed in claim 9, in which the processor unit is set up in such a way that the classes are assessed and a class for which the assessment lies below a predefined second threshold value is screened out.

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Abstract

Method and arrangement for reducing a number of measured values of a technical system

A method of reducing a number of measured values of the technical system is specified in which the measured values are divided into classes in accordance with predefined criteria. The measured values in a class are assessed and those measured values whose assessment lies below a predefined first threshold value are screened out.

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FIG 1

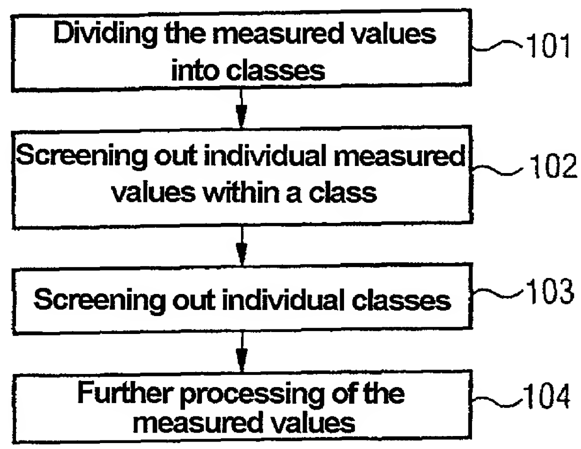

FIG 2

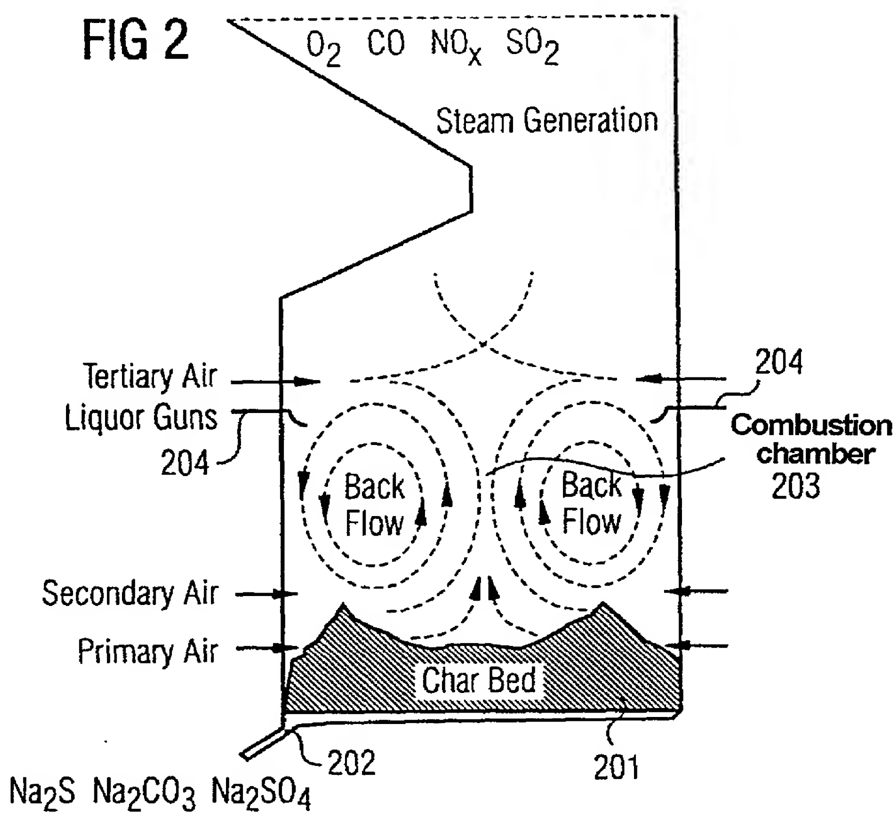

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FIG 3

Input variables		
	Measured variable	Description
1	FI 7081	BL Flow
2	QI 7082 A	Dry Solids Content
3	FIC 7280 X	PA Primary Air
4	FIC 7281 X	SA Secondary Air
5	FIC 7282 X	TA Tertiary Air
6	PI 7283	PA Pressure
7	PI 7284	SA Pressure
8	PHI 7285	TA Pressure
9	TIC 7288 X	PA Temperature
10	TIC 7289 X	SA Temperature
11	PIC 7305 X	Press Induced Draft
12	HO 7338	Oil Valve
13	TI 7347	BL Temperature
14	PIC 7349 X	BL Front Pressure
15	PIC 7351 X	BL Back Pressure

FIG 4

Actuating variables		
	Measured variable	Description
1	FIC 7280 X	PA Primary Air
2	FIC 7281 X	SA Secondary Air
3	FIC 7282 X	TA Tertiary Air
4	PIC 7349 X	BL Front Pressure

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FIG 5

Output variables		
	Measured variable	Description
1	TIC 7249 X	Steam Temperature
2	FI 7250	Steam Production
3	QI 7322	O_2
4	TI 7323	Smoke Temperature
5	QI 7331	H_2S
6	QI 7332	SO_2
7	QIC 7333 X	CO
8	QIC 7370 X	Spec. Weight of Green Liquor
9	QI 7531	NO
10	IBM 8096	Reduction Efficiency
11	IBM 8109	PH Value
12	TI 7352	Bed Temperature
13	IBM 8015	$NaOH$
14	IBM 8016	Na_2S
15	IBM 8017	Na_2CO_3

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Declaration and Power of Attorney For Patent Application
Erklärung Für Patentanmeldungen Mit Vollmacht
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Als nachstehend benannter Erfinder erkläre ich hiermit an Eides Statt:

As a below named inventor, I hereby declare that

dass mein Wohnsitz, meine Postanschrift, und meine Staatsangehörigkeit den im Nachstehenden nach meinem Namen aufgeführten Angaben entsprechen,

My residence, post office address and citizenship are as stated below next to my name,

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Verfahren und Anordnung zur Reduktion einer Anzahl von Messwerten eines technischen Systems

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

____

deren Beschreibung

(zutreffendjhaes ankreuzen)

☐ hier beigefügt ist.

☐ am ____________ als
PCT internationale Anmeldung
PCT Anmeldungsnummer ____________
Eingereicht wurde und am ____________
Abgeändert wurde (falls tatsachlich abgeändert)

the specification of which

(check one)

☐ is attached hereto.

☐ was filed on ____________ as
PCT international application
PCT Application No ____________
and was amended on ____________
(if applicable)

Ich bestätige hiermit, dass ich den Inhalt der obigen Patentanmeldung einschliesslich der Ansprüche durchgesehen und verstanden habe, die eventuell durch einen Zusatzantrag wie oben erwähnt abgeändert wurde.

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims as amended by any amendment referred to above.

Ich erkenne meine Pflicht zur Offenbarung irgendwelcher Informationen, die für die Prüfung der vorliegenden Anmeldung in Einklang mit Absatz 37, Bundesgesetzbuch, Paragraph 1.56(a) von Wichtigkeit sind, an.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, §1.56(a).

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Prior foreign appplications
Priorität beansprucht

Priority Claimed

Number / Nummer	Country / Land	Day Month Year Filed / Tag Monat Jahr eingereicht	Yes / Ja	No / Nein
198 55 877.5	Germany	03.12.1998	☒	☐
			☐	☐
			☐	☐

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(Application Serial No.) (Anmeldeseriennummer)	(Filing Date) (Anmeldedatum)	(Status) (patentiert, anhängig, aufgegeben)	(Status) (patented, pending, abandoned)

(Application Serial No.) (Anmeldeseriennummer)	(Filing Date) (Anmeldedatum)	(Status) (patentiert, anhängig, aufgeben)	(Status) (patented, pending, abandoned)

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German Language Declaration

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POWER OF ATTORNEY As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith. *(list name and registration number)*

And I hereby appoint

(18) Messrs. John D. Simpson (Registration No. 19,842) Lewis T. Steadman (17,074), William C Stueber ~~(16,453)~~, P Phillips Connor (19,259), Dennis A Gross ~~(24,410)~~, Marvin Moody (16,549), Steven H. Noll (28,982), Brett A. Valiquet (27,841), Thomas I. Ross (29,275), Kevin W. Guynn (29,927), Edward A Lehmann ~~(22,312)~~, James D. Hobart (24,149), Robert M. Barrett (30,142), James Van Santen (16,584), J. Arthur Gross (13,615), Richard J. Schwarz (13,472) and Melvin A. Robinson (31,870), David R. Metzger (32,919), John R. Garrett (27,888) all members of the firm of Hill, Steadman & Simpson, A Professional Corporation.

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1-00

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Unterschrift des Erfinders / Datum: 11.11.99	Inventor's signature / Date
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Staatsangehörigkeit: Bundesrepublik Deutschland	Citizenship
Postanschrift: Paul-Lincke-Str. 15	Post Office Addess
D-86199 Augsburg Bundesrepublik Deutschland	

2-00

Voller Name des zweiten Miterfinders (falls zutreffend): STURM, Thomas	Full name of second joint inventor, if any:
Unterschrift des Erfinders / Datum: 11.11.99	Second Inventor's signature / Date
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Staatsangehörigkeit: Bundesrepublik Deutschland	Citizenship
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D-81673 München Bundesrepublik Deutschland	

(Bitte entsprechende Informationen und Unterschriften im Falle von dritten und weiteren Miterfindern angeben).

(Supply similar information and signature for third and subsequent joint inventors).

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